414 Rec'd PCT/PTO 14 NOV 2000

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	ATTORNEY'S DOCKET NUMBER 1878/00037 U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 09/700316

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/SE99/00751	5 May 1999	15 May 1998

TITLE OF INVENTION

ROBOT SIMULATOR

APPLICANT(S) FOR DO/EO/US

Ohberg, Lars-Olof , Hedman, Bernt-Ove

IPE JC68 NOV 14 2000 PATENT & TRADEMARK OFFICE

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. § 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the Annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☐ A FIRST preliminary amendment.
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter
16. ☒ Other items or information: International Search Report, International Preliminary Examination Report

529 Rec'd PCT/PTC 14 NOV 2000

U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 09/700316	INTERNATIONAL APPLICATION NO. PCT/SE99/00751	ATTORNEY'S DOCKET NUMBER 1878/00037	
☒ The following fees are submitted:		CALCULATIONS	PTO USE ONLY
Basic National Fee (37 CFR 1.492(a)(1)-(5)): Search Report has been prepared by the EPO or JPO..**$860.00** International preliminary examination fee paid to USPTO (37 CFR 1.482) ....$69 **0.00** No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2))...**$760.00** Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO..**$1,000.00** International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4)..**$100.00**			
ENTER APPROPRIATE BASIC FEE AMOUNT =		$1000	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).		$	

Claims	Number Filed	Number Extra	Rate		
Total Claims	6- 20 =	0	X **$18.00**	$	
Independent Claims	1- 3 =	0	X **$80.00**	$	
Multiple dependent claim(s)(if applicable)			+ **$270.00**	$	
TOTAL OF ABOVE CALCULATIONS =				**$1000**	
Reduction by 1/2 for filing by small entity, if applicable.				$	
SUBTOTAL =				$1000	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$	
TOTAL NATIONAL FEE =				$1000	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$ 40	
TOTAL FEES ENCLOSED =				$1040	
				Amount to be: refunded	$
				charged	$

a. ☒ A check in the amount of $1040 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. <u>22-0185</u> in the amount of $__________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Director is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 22-0185. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b) must be filed and granted to restore the application to pending status

SEND ALL CORRESPONDENCE TO:
Pollock, Vande Sande & Amernick, R.L.L.P.
1990 M Street, N.W., Suite 800
Washington, DC 20036-3425

SIGNATURE

Burton A. Amernick
NAME

24,852
REGISTRATION NUMBER

09/700316
529 Rec'd PCT/PTC 14 NOV 2000

1/PRTS

ROBOT SIMULATOR

TECHNICAL FIELD

The invention presented here concerns a method and a device for simulating an aircraft missile during testing of an aircraft system that includes a weapons system for controlling the missile.

STATE OF THE ART

Modern aircraft comprise flying-control systems that include computers, electronics and software for monitoring and controlling the functions of the aircraft. This system. referred to here as the aircraft system. in military aircraft includes a weapons system whose purpose is to monitor and operate the various functions of the aircraft's weapons. Included in the said functions of the weapons is control of missiles with which the aircraft may be equipped. Such missiles may be fitted with a target seeker, which can take up a specific position, directed for example at a target. Guidance of the target seeker towards the target is accomplished by means of a signal from the weapons system.

The target seeker in the missile is controlled by a control loop, which as is usual comprises a trouble signal, in this case from the weapons system to the target seeker. and an actual value signal containing an actual value describing the actual position of the target seeker. In practice. control is commonly effected by coils fitted to the trouble signal, which controls a magnetic freely-suspended gyro, which in turn causes the target seeker to rotate itself to the guided position. The actual value signal is created by means of a purpose designed fixed coil which detects the gyro's position and sends the information via the actual value signal. The actual value signal is a sinusoidal shaped signal the amplitude of which describes the target seeker's torsional angle and whose phase position relative to a reference signal describes the direction in which the gyro and the target seeker are rotated.

During testing of aircraft systems as described above it common to use a missile of the type in question and connect this to a specially designed gun carriage on the aircraft. The missile has in such cases been disengaged from its drive motor and its explosive components, i.e. the active weaponery.

Naturally, it is impractical to have to handle missiles in this manner in order to be able to perform a test of the system and all its functions.

A known method for simulating a missile involves taking a discrete measurement of the command signal from the weapons system to the missile, imitating the operations of the missile and sending back a simulated actual value signal to the weapons system. A difficulty with such a simplified simulation is to be able to measure the command signal and interpret it in the same way as the missile would.

DESCRIPTION OF THE INVENTION

One aspect of the invention consists of a method specified in the independent claim 1.

Simulation of a missile according to the aspect of the invention permits continuous measurement of the command signal in the aircraft system.

The principles of simulation of the missile can be summarized as follows:
A signal with the command position for the missile's target seeker is received by a summing unit in the aircraft's weapons system. In addition, the signal for the actual position of the target seeker in the missile is received by the said summing unit. A trouble signal equivalent to the deviation between the command position and the actual position is obtained as an output signal from the summing unit. The trouble signal is used as a control signal for the target seeker.

During missile simulation the trouble signal first passes a hardware interface which adapts the trouble signal to a computer model for the missile's target seeker. The error in amplitude and angle of the vector which specifies the direction to the target is sent from the interface to the computer model. The behaviour of the actual missile is simulated in the computer model, whereupon a simulated actual value of amplitude and angle of the position of the target seeker is sent back to the interface, where an actual value signal adapted to the weapons system is created. The said actual value signal is inverted so as to give a negative contribution when the actual value signal is added in the said summing unit.

During simulation there are time-continuous signals before the interface and time-discrete signals after the interface, where these signals are fed to the computer model. The actual missile operates only with time-continuous signals. The time-discrete signals are obtained by a sampling of the input time-continuous signals. It is important here that the signals at the moment of sampling as closely as possible assume the values that they would in the actual time-continuous system at corresponding points in time and that noise and interference are suppressed.

The actual position (actual value) of the target seeker can be simply recorded using the method presented here, since the actual value is produced by a computer. When using a real missile in the test the actual value must be measured instead. This is unnecessary, since it is precisely this measurement in the weapons system that is, for example, verified by the aspect of the invention.

DESCRIPTION OF FIGURES

Figure 1 shows schematically the principles for construction of the equipment used in simulating a missile according to the aspect of the invention.

Figures 2a and 2b illustrate how the target seeker's position is represented graphically.

EMBODIMENTS OF THE INVENTION

A number of examples of the described aspect of the invention are described below with the aid of the figures.

Figure 1 shows a block representing the weapons system 1 of the aircraft. This includes a summing unit 2, which receives a command signal 3 indicating the position for the target. The summing unit 2 also receives an actual value signal 4 from the missile model 5, which simulates the operation of the missile during target guidance. Since the actual value signal 4 produces a negative contribution to the summing unit 2 there will be a difference between the

command position and the actual position of the missile simulator's target seeker, where this difference is used as a trouble signal 6 for the missile model 5. The previously mentioned hardware interface is represented by block 7 in the figure. The trouble signal 6 to the interface 7 is a continuous signal, which is sampled in the interface 7 and provides sample values for the deviation ΔA in the amplitude and for the deviation $\Delta\varphi$ in the phase angle. These two values are time-discrete values. The actual values for the position of the simulated target seeker is sent from the missile model 5 back to the interface 7 in the form of amplitude A and phase angle φ. These values are converted in the interface 7 to the said time-continuous actual value signal 4, which is returned to the weapons system's 1 summing unit 2. A reference signal 8 is also sent from the interface 7 to the weapons system 1.

The different signals are given by:

actual position: $S = A\sin(\omega t + \varphi)$

commanded position: $S^c = A^c \sin(\omega t + \varphi^c) = (A + \Delta A) \sin(\omega t + \varphi + \Delta\varphi)$

reference signal: $A^r \sin(\omega t)$

trouble signal: $\Delta = Sc - S$ predicted p radians, that is

$$\Delta = A^c \sin(\omega t + \varphi^c + p) - A \sin(\omega t + \varphi + p)$$

By measuring the trouble signal 6 in the interface 7 and by exploiting the fact that the actual value is known, ΔA and $\Delta\varphi$ are determined as closely as possible. This can be done in different ways. The simplest way is to measure Δ at two points in time, for example when the signal S is at its maximum and when the signal S passes through zero on a certain flank and then from these two determined relationships work out ΔA and $\Delta\varphi$. Another way is to use a measuring method involving generation of a mean. How the correlation method is used is described below.

From the trouble signal 6 two new signals are produced as follows

$\Delta\sin = \Delta \text{ x } \sin(\omega t + \varphi)$

$\Delta\cos = \Delta \text{ x } \cos(\omega t + \varphi)$

both functions of which are integrated giving the integrals

$$I_1 = \int_0^{2\pi/\omega} \Delta \sin dt \quad \text{and} \quad I_2 = \int_0^{2\pi/\omega} \Delta \cos dt$$

From I_1 and I_2, ΔA and $\Delta\varphi$ can then be solved.

By derivation one gets

$$\Delta\varphi = \begin{cases} a\tan 2(T,N) - p & \text{if} \quad (T)^2 + (N)^2 > k \\ 0.0 & \text{otherwise} \end{cases},$$

where $T = \omega I_2 + \pi A\sin p$ and $N = \omega I_1 + \pi A\cos p$

and

$$\Delta A = \begin{cases} \dfrac{\omega I_1 + \pi A \cos p}{\pi \cos(\Delta\varphi + p)} - A & \text{if} \quad |\sin(\Delta\varphi + p)| < 0.5 \\ \dfrac{\omega I_2 + \pi A \sin p}{\pi \sin(\Delta\varphi + p)} - A & \text{otherwise} \end{cases}$$

In practice a numerical method can be employed to calculate the integrals. In the method according to the invention an approximation using sums is used in the interface 7. The summation in the example is performed at 512 points evenly spread out over the period of time. Such an approximation gives satisfactorily good results. Since the integration is performed over the whole period of the signal it takes a certain amount of time from the moment the input signal enters the interface 7 until the output signal from the interface 7 becomes available. One result of this is that there is a delay of one sample period during simulation of the position of the target seeker.

Naturally, mathematical methods other than the above correlation method can be used. The described correlation method has, however, been shown to work very well. In particular, this method has proved favourable since it avoids the problem of sensitiveness to interference.

By using the shown correlation method it has been established how the target seeker's actual position differs from the commanded one. What remains to be done is to analyse how the target seeker responds to the error and to simulate this. Fig. 2a shows the definition of the target seeker's position vector S in a three-dimensional coordinate system, with the x-axis

pointing straight ahead in relation to the aircraft, where the angle λ shows the angle of the position vector in relation to the x-axis, and δ shows the angle of the position vector in relation to the y-axis, with the position vector projected onto the yz-plane. In figure 2b, the actual position of the target seeker is indicated by the vector S_0 and its commanded position by S^c. The angle between these vectors η_0 can be called the angle of error and this is to be minimised.

A mathematical treatment of these vectors results in the equation

$$\overline{S}_0 = \begin{pmatrix} x_0 \\ y_0 \\ z_0 \end{pmatrix} = \begin{pmatrix} \cos A_0 \\ \sin A_0 \cos \varphi_0 \\ \sin A_0 \sin \varphi_0 \end{pmatrix} \quad \text{and} \quad \overline{S}_C = \begin{pmatrix} x^C \\ y^C \\ z^C \end{pmatrix} = \begin{pmatrix} \cos A^C \\ \sin A^C \cos \varphi^C \\ \sin A^C \sin \varphi^C \end{pmatrix}$$

The size of the error is given by

$$d = \left| S^C - S_0 \right| = \sqrt{(x^C - x_0)^2 + (y^C - y_0)^2 + (z^C - z_0)^2}$$

which is then recalculated to an angle of error

$$\eta_0 = 2\operatorname{asin}\frac{d}{2}.$$

During a sample period the angle of error changes to

$$\eta = \eta_0 e^{-25\times 0.02} \quad \text{if } \eta_0 \le 1° \text{, or to}$$

$$\eta = \eta_0 - 25 \cdot 0.02 \frac{\pi}{180} \quad \text{if } \eta_0 > 1°.$$

The new actual position will be

$$\overline{S} = \overline{S_0} + \frac{\sin(\eta_0 - \eta)}{\sin(\pi/2 + \eta - \eta_0/2)} \cdot \frac{\overline{S^C} - \overline{S_0}}{d} \quad \text{if } \eta_0 > 1°\text{, or}$$

$$\overline{S} = \overline{S_0} + (1 - e^{-25\times 0.02})(\overline{S^C} - \overline{S_0}) \quad \text{if } \eta_0 \le 1°$$

This vector is extended so that a unit vector is obtained

$$\bar{S} = \frac{\bar{S}}{|\bar{S}|}\ .$$

Subsequently the conversion to polar coordinates is made again

$$A = a\tan 2(\sqrt{y^2 + z^2}, x)$$
$$\varphi = a\tan 2(z, y)\ .$$

When the target seeker positions itself it does so in such a way that S_0 moves in a plane toward S^c, i.e. the point of the vector follows the course of a large circle. The target seeker is, however, unable to move at unlimited speeds, but takes a certain amount of time in order to position itself. There are two conditions regarding the target seeker's movement; one is that the movement shall be in one plane, the other is that the speed is limited. These circumstances are taken into account in the derivation of the relationship above.

CLAIMS

1. Method for simulating an actual missile by means of an missile simulator during testing of an aircraft system which comprises a weapons system (1). where the missile is controlled from the weapons system (1) by a trouble signal (6) in a control loop by means of the said trouble signal (6) positioning a target seeker in the missile and through the sending back of the target seeker's position to the weapons system via an actual value signal (8),

characterized in that

a) the target seeker in the missile is commanded by the weapons system (1) to adopt a predetermined position,

b) the missile simulator measures the control loop's trouble signal (6), generates an actual value for the position of the target seeker and sends the actual value (8) to the weapons system (1),

c) the weapons system (1) calculates a new trouble signal (6) for the control loop,

d) steps b to c are repeated during the test.

2. Method according to claim 1, characterized in that the trouble signal (6) is measured continuously in an interface (7) and that the sampled values for the error in amplitude (A) and error in phase angle (φ), which is given by the difference between the vector (S^c), which gives the position for a command target, and the vector (S_0), which gives the target seeker's actual value, are determined and sent to a missile model (5) in the missile simulator.

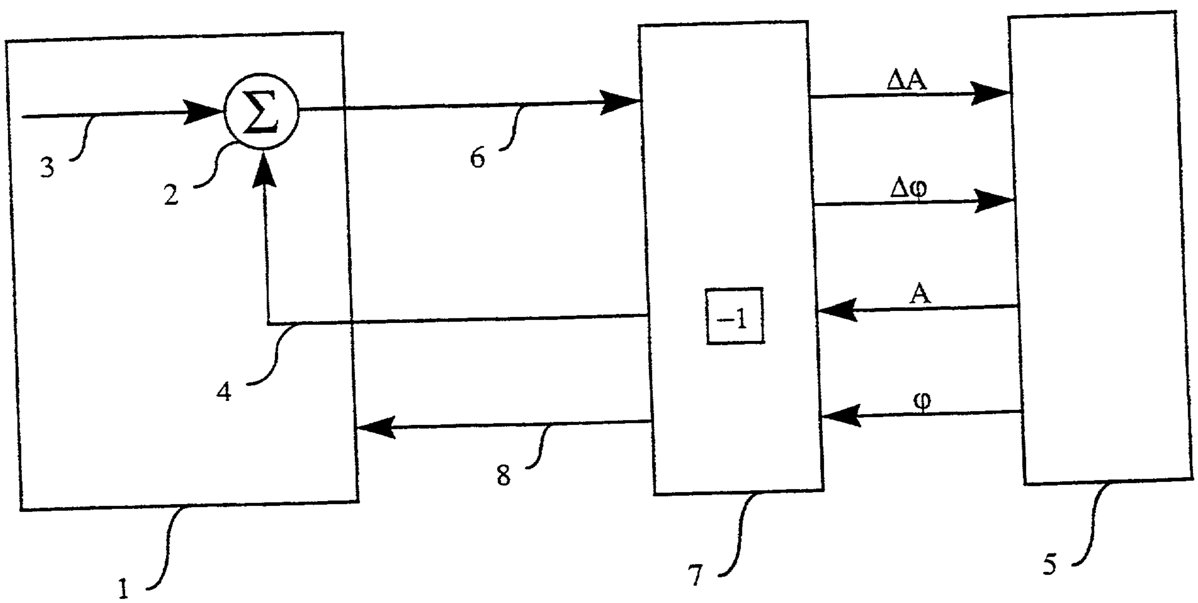
3. Method according to claim 2, characterized in that for each sample value of the trouble signal (6) the missile model (5) calculates a new actual value ($\overline{S}$) of the target seeker's position and sends this actual value ($\overline{S}$) back to the interface (7) in the form of actual values for the position vector's amplitude (A) and the position vector's phase angle (φ).

4. Method according to claim 3, characterized in that the interface (7) reproduces a continuous actual value signal (8) from the values for amplitude (A) and phase angle (φ) obtained from the missile model (5).

5. Method according to claim 4, characterized in that the interface (7) inverts the actual value signal (8).

6. Method according to claim 5, characterized in that the trouble signal (6) is generated in a summing unit (2) in the weapons system (1) by summing of the signal from the weapons system (1), which gives the position for a commanded target, and the inverted actual value signal (8) in a summing unit (2).

Fig. 1



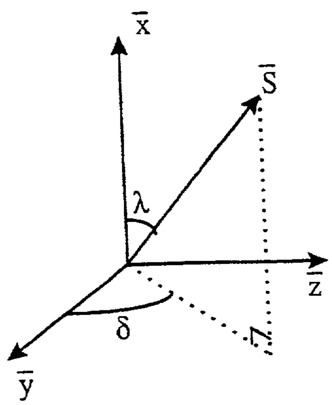


Fig. 2a

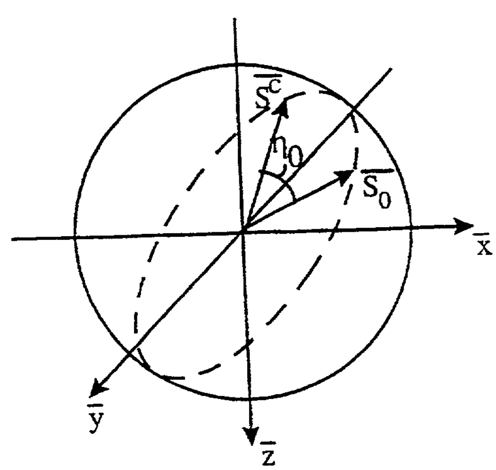


Fig. 2b

DECLARATION FOR PATENT APPLICATION

1878/00037

As a below-named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

ROBOT SIMULATOR

the specification of which: (check one)

[ ] is attached hereto. [XX] was filed on May 5, 1999, as United States Patent Application Serial No. or PCT International Application Number PCT/SE99/00751, and was amended on ________ 19__ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with 37 CFR § 1.56(a).

Prior Foreign Application(s): I hereby claim foreign priority benefits under 35 U.S.C. § 119(a)-(d) or §365(b) of any foreign application(s) for patent or inventor's certificate listed below, or § 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

			Priority Claimed	
9801736-1	Sweden	15/May/1998	[XX]	[ ]
(Application No.)	(Country)	(Day/Month/Year Filed)	YES	NO
			[ ]	[ ]
(Application No.)	(Country)	(Day/Month/Year Filed)	YES	NO
			[ ]	[ ]
(Application No.)	(Country)	(Day/Month/Year Filed)	YES	NO

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below:

Application No.	Filing Date

I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s) listed below or 34 U.S.C. § 365(c) of any PCT International Application designating the United States of America listed below, and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application or PCT application in the manner provided by 35 U.S.C. § 112, first paragraph, I acknowledge the duty to disclose material information as defined in 37 CFR § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(U.S. or PCT Application Serial No.)	(U.S. or PCT Filing Date)	(Status - patented, pending, abandoned)
(U.S. or PCT Application Serial No.)	(U.S. or PCT Filing Date)	(Status - patented, pending, abandoned)

I hereby appoint the following registered practitioners: George Vande Sande, Registration No. 17,276; Burton A. Amernick, Registration No. 24,852; Richard Wiener, Registration No. 18,741; Townsend M. Belser, Jr., Registration No. 22,956; Morris Liss, Registration No. 24,510; George R. Pettit, Registration No. 27,369; Elzbieta Chlopecka, Registration No. 32,767; William E. Curry, Registration No. 43,572; David W. Ward, Registration No. 45,198, and John A. Evans, Ph.D., Registration No. 44,100, with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

10

Send Correspondence and Direct Telephone Calls to:
Burton A. Amernick
(202) 331-7111

Burton A. Amernick
Pollock, Vande Sande & Amernick, R.L.L.P.
P.O. Box 19088
Washington, D.C. 20036–0088 U.S.A.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

1-00 Full name of sole or first inventor: Lars-Olof Öhberg

Inventor's Signature: X Lars-Olof Öhberg Date: 2000-11-03

Residence Address: Vindarnas vag 9, S-582 72 Linkoping, Sweden SEX

Citizenship: Sweden

Post Office Address: Same as above

[XX] See next page for additional inventors

DECLARATION FOR PATENT APPLICATION
Page 2

2-00 Full name of second joint inventor (if any) Bernt-Ove Hedman

Inventor's Signature X Bernt Ove Hedman Date 11/02 2000 X
Residence Address Rattaregatan 50, S-583 33 Linkoping, Sweden SEX
Citizenship Sweden
Post Office Address Same as above

Full name of third joint inventor (if any)

Inventor's Signature Date
Residence Address
Citizenship
Post Office Address

Full name of fourth joint inventor (if any)

Inventor's Signature Date
Residence Address
Citizenship
Post Office Address

Full name of fifth joint inventor (if any)

Inventor's Signature Date
Residence Address
Citizenship
Post Office Address

Full name of sixth joint inventor (if any)

Inventor's Signature Date
Residence Address
Citizenship
Post Office Address

Full name of seventh joint inventor (if any)

Inventor's Signature Date
Residence Address
Citizenship
Post Office Address

Full name of eighth joint inventor (if any)

Inventor's Signature Date
Residence Address
Citizenship
Post Office Address